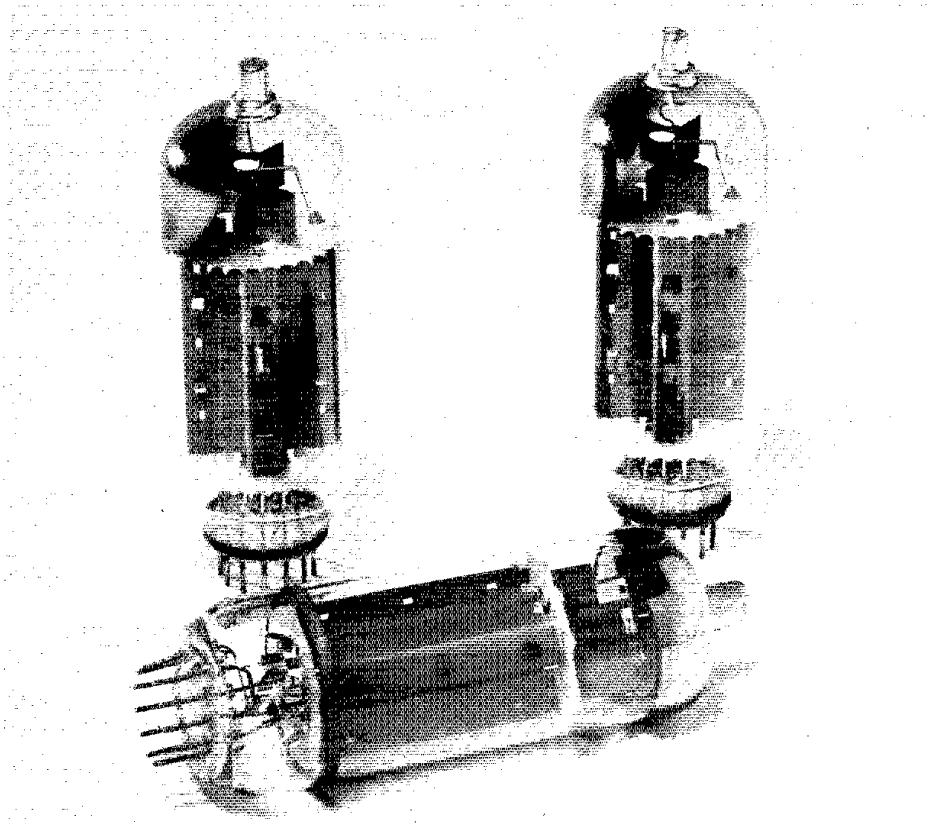
Some Thoughts About TV Sweep Tubes



There's nothing wrong with using TV sweep tubes as rf power amplifiers. Here are some observations.

By Doug DeMaw,* W1FB

A stigma seems to have developed concerning the use of horizontal-output tubes (sweep tubes) in amateur transmitters. Some operators fear them because of their thermal fragility and others claim they're no good as linear amplifiers for ssb operation. Sure, there's a bit of truth connected with both concerns, but there are some good features too!

In many parts of the world it is easier to purchase TV sweep tubes locally than it is to find a 6146B. Surely this is a plus feature. Also, a number of sweep tubes cost less than 6146s do.

In simple terms, the thermal-fragility problem can be explained by stating that the key-down (continuous-carrier mode) is limited to short periods compared to that of 6146s. Too long a period (generally in excess of 30 to 45 seconds) will cause excessive tube heating and subsequent damage or failure. The reason for this limitation is that sweep tubes are designed for high peak currents of short duration (pulse service), but not for high levels of

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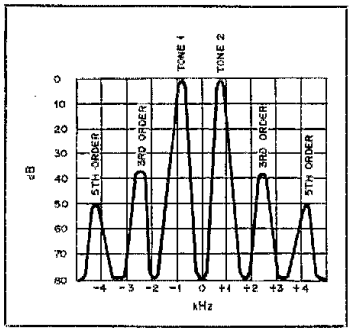


Fig. 1 — A classic spectrum display of what would be seen at the transmitter output during a two-tone IMD test. The maximum power output is represented by the peaks labeled tone 1 and tone 2. The 3rd- and 5th-order distortion products are displayed to the left and right of the desired signal. The 3rd-order products are 39 dB below full power and the 5th-order products are 50 dB below full output. Ideally, there would be no IMD products showing, and there would be some noise appearing as "grass" near the baseline of the spectral display. The higher the level of the 3rd- and 5th-order products, the lower the quality of the ssb signal.

Table 1

Some Sweep-Tube Parameters

Type	C (Input) (pF)	Input Resonant Frequency (MHz)	C (Output) (pF)	Output Resonant Frequency (MHz)	Probable*** Upper Frequency Limit of Operation (MHz)
6GJ5	19.1	190	10.0	190	150
6HF5*	25.5	86	16.3	141	60
6HF5**	26.7	100	16.3	141	75
6JB6	19.1	190	10.5	200	145
6JE6	24.3	82	14.5	152	60
6JM6	17.2	200	10.3	194	150
6JG6	22.9	187	14.7	226	150

*One grid connection.
**Two grid connections.
***75 percent of self-resonant frequency.
Data courtesy of Sylvania

continuous current. They are entirely suitable, however, for ICAS (intermittent commercial and amateur service) operation.

In linear-mode service, they do not yield the IMD (intermodulation distortion) quality which is typical of 6146 tubes at full rated power, respectively. In a properly designed and operated amplifier, however, it is possible to obtain sweep-tube linearity which nearly approaches that of the 6146 tube. For example, the Yaesu FT-101E which was reviewed in September 1976 *QST* exhibited 3rd-order distortion products which were 34 dB down from full output. The '101 uses sweep tubes in the PA. The Kenwood TS-820, which contains 6146Bs in the PA, was reviewed in the same issue. The 3rd-order products from the '820 were 39 dB below full power.

The worst-case IMD observed in the ARRL lab from a rig which utilized sweep tubes was −27 dB. The ARRL technical staff feels that an acceptable level for 3rd- and 5th-order distortion products (see Fig. 1) is 30 dB or greater below full power. Therefore, the FT-101E and TS-820 units are considered above average in terms of IMD.

The now-defunct Galaxy Company once marketed a 2-kW PEP linear amplifier (model 2000+) which contained 10 sweep tubes in parallel. The amplifier operated Class AB1 and was grid-driven across a 50-ohm noninductive power resistor. The measured 3rd- and 5th-order distortion products were 31 dB below full amplifier power output.

Another example of acceptable performance was seen when a linear amplifier built by the author was tested by means of a spectrum analyzer. The circuit contained four 6KD6 sweep tubes in parallel, cathode driven and in Class AB1. The IMD products were observed at −30 dB or better. Peak output power was 800 W.[1]

Operating Frequency

Generally speaking, TV sweep tubes are able to give acceptable performance up to 30 MHz. The 6146B, on the other hand, is good well into the vhf region.

The useful upper frequency limits of sweep tubes are determined by the internal lead lengths, the input capacitance and the output capacitance. Since these tubes were designed for low-frequency TV service (15.750 kHz), the manufacturers are not concerned with the aforementioned "problem causers." The high terminal capacitances of the tubes tend to shunt the rf currents to ground. This malady becomes more pronounced as the operating frequency is increased. The high-input C makes the tube hard to drive and presents impedance-matching problems. The high-output C can cause excessive currents inside the tube, causing gradual performance degradation or complete failure. Therefore, it is prudent to choose sweep tubes with short internal leads and minimum terminal capacitance. The effect of long internal leads is one of the lead inductance resonating with the internal capacitance at some specified high frequency. This condition can cause stray rf currents to be high, ultimately harming the tube. Vhf parasitic oscillation is enhanced greatly if the tube chosen has input and output self-resonant frequencies which are close in frequency. Table 1 shows how various popular sweep tubes compare in this respect. Parasitic chokes of the type shown in Fig. 2 (Z1) can be installed to prevent parasitics.

The writer made but one attempt to use a sweep tube at vhf. A 6JB6 was hooked up for grounded-grid operation and driven from a 5-W exciter. An output of 25 watts was obtained, but the tube efficiency was rather dismal — roughly 30 percent after considerable optimizing. The tank circuit was designed to absorb the tube output capacitance (Fig. 3). The 19 pF of input C presented no special problems.

The Problems of Parallel Use

No matter what tube a builder may choose for the amplifier, paralleling two or more such tubes creates design problems. A matter of special concern is the current drawn by each tube in the string. Dynamic balance is essential to ensure that no single tube in the combination "hogs" the plate current. If, for example, six 6HF5s were connected in parallel, and the g_m (transconductance) of one was substantially higher than the rest, the one with the high g_m would probably be driven well beyond its safe dissipation rating. The result would be disastrous as you sat and watched the anode turn red, just before the glass envelope melted or cracked! Sweep tubes are especially prone to this ailment because of their high g_m ratings: The 6KD6, for one, has a transconductance of 14,000 micromhos!

A not-so-practical solution to the problem of current sharing is to install a matched set of tubes. For the amateur this is not good news, as *many* tubes would be necessary in order to grade them out for the matched set required in the amplifier.

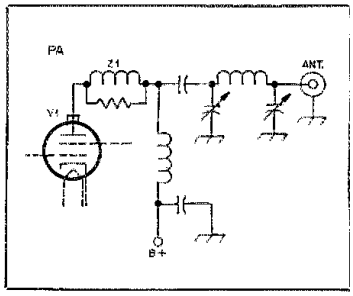


Fig. 2 — Schematic illustration of an amplifier which contains a parasitic suppressor (Z1). This component can be fashioned from a 100-Ω, 2-watt composition resistor. The coil is wound over the resistor body and made common to the resistor pigtails. Eight turns of no. 20 enameled wire are suitable for the coil.

[1]Notes appear on page 15.

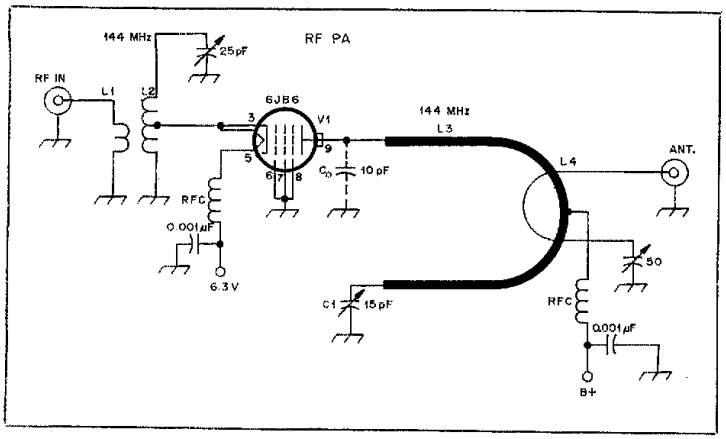


Fig. 3 — Circuit of an experimental 144-MHz grounded-grid amplifier which used a 6JB6 sweep tube (see text). C_o is the tube output C. L3 is dimensioned so that resonance occurs when C1 is set at 10 pF.

A simple method for balancing the tubes was worked out by the author (note 1). The scheme is shown in Fig. 4. With full drive to the amplifier, the bias-adjust control for each tube is tweaked for equal plate currents. The resting plate currents may be unequal as a result, but they will not be too low to affect linearity of the amplifier. Although separate meters are shown for each tube in Fig. 4, they aren't necessary. A single 0-1 ampere meter can be employed to meter all four tubes at one time. Tube balance can be measured by installing a 10-ohm, 1-watt resistor in series with each cathode lead. R1 through R4 are then adjusted to obtain equal voltages across the 10-ohm resistors at peak drive. When choosing sweep tubes for grounded-grid service (Fig. 4), it is mandatory to select the types which have the beam-forming plates brought out to a separate base pin. This connection should be returned to rf ground along with the

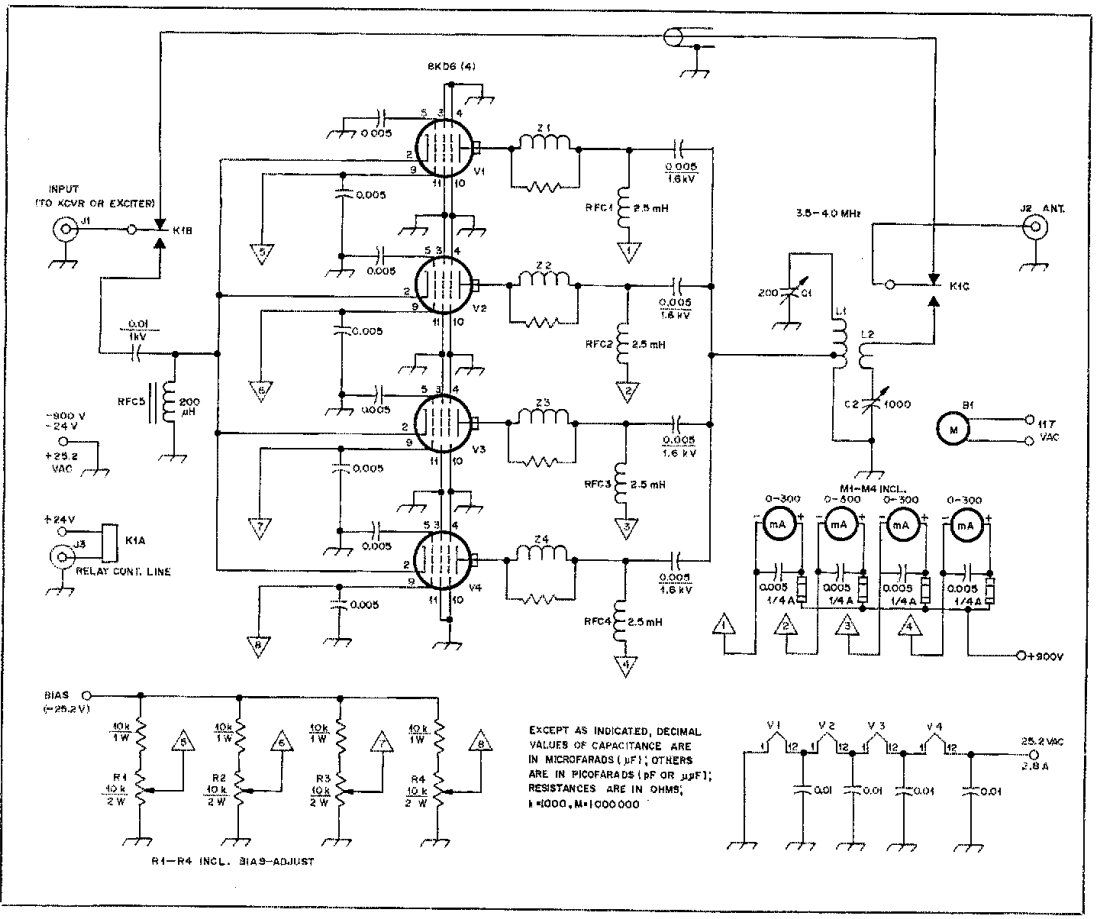


Fig. 4 — A grounded-grid sweep-tube linear amplifier which contains four 6KD6 tubes. Dynamic balance is ensured by means of R1 through R4. These controls are set to provide equal plate currents for the four tubes at peak drive periods (see text and note 1). This circuit originally appeared in July 1968 *QST*, page 31.

control and screen grids. Some sweep tubes have their beam-forming plates connected to the cathode *inside* the tube. In grounded-grid service, this will lead to amplifier self-oscillation, especially as the operating frequency is increased.

Another complication which results from paralleling several tubes is a marked increase in the combined input and output capacitance. Needless to say, as either of these values become elevated, the greater the unwanted rf-shunting effect discussed earlier. Severe limitations can be imposed on the upper frequency range of the amplifier. For example, the 6KD6 tube has a rated input C of 40 pF and an output C of 16 pF. Six of these tubes in parallel would yield 240 and 64 pF, respectively. The output capacitance could be absorbed in the plate-tank circuit, but the input capacitance would have to be dealt with by means of matching networks similar to those used with rf power transistors. In fact, the plate impedance of several sweep tubes in parallel becomes pretty low, causing the designer to move in the direction of transistor matching networks. A six-tube Class B amplifier (sweep tube) might develop 1 ampere of plate current at peak drive. If the plate voltage were 900 — a typical value for amateur service — the plate impedance would be approximately 572 ohms, as derived from

$$R_L = \frac{E_p}{1.57 \times A}$$

where

E_p is the plate voltage,

R_L is the plate impedance in ohms and

A is the plate current in amperes.

In basic terms, the low-impedance and high-output C makes conventional tank circuits impractical at frequencies above 40 meters. If a pi network with a loaded *Q* of, say, 12 were desired, the resultant values of C and L would become quite impractical at the upper end of the hf spectrum. For this reason, transistor types of networks become more desirable.[2]

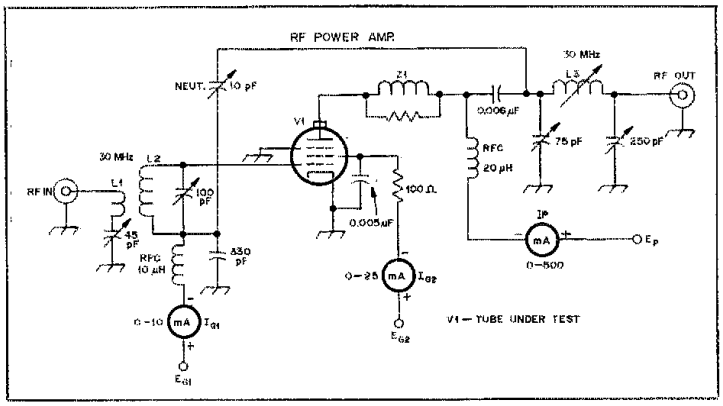


Fig. 5 — Schematic diagram of the 30-MHz test circuit used by Sylvania to collect rf operating data for six common TV sweep tubes. Z1 is similar to that of Fig. 2. L2 and L3 are chosen to provide a high operating tank *Q*.

Operating Parameters

In 1964, Sylvania Electric Products Inc. took the trouble to test their sweep tubes for rf service up to 30 MHz. Data were compiled for Class C and Class AB1 operation for six popular tubes. Tables 2 and 3 contain the information as it was presented in *Sylvania Industrial News* for November and December 1964. Table 1 was published by Sylvania at the same time. These are probably the only meaningful rf data developed for deflection tubes.

It was mentioned earlier that a plate voltage of 900 was typical for sweep tubes in amateur service.[3] That statement should be clarified by saying that 900 is more typical in homemade linear amplifiers than it is in commercial equipment. Tables 2 and 3 specify 500 volts as

Table 2

Class C Operation ICAS — 30 MHz

Type	(1) E_{G1} V dc	(1) E_{G2} V dc	(1) E_p V dc	Peak E_{G1} V rf	(1) I_{G1} mA dc	I_{G2} mA dc	I_p mA dc	Grid 1 Driving Power (Approx.) Watts	Grid 2 Dissipation Watts	Plate Input Power Watts	RF Power Output Watts	Efficiency (%)	Plate Dissipation Watts	(2) Circuit Loss Watts
6GJ5	−75	200	500	61	5.0	14.9	180	0.43	2.99	90.0	62.7	69.5	22.0	5.3
6HF5	−85	140	500	67	8.0	12.5	232	0.76	1.75	116.0	77.0	66.0	35.0	4.0
6JB6	−75	200	500	61	5.0	13.3	180	0.43	2.66	90.0	62.7	69.5	22.0	5.3
6JE6	−85	125	500	72	8.0	17.2	222	0.82	2.15	111.0	76.3	69.0	30.0	4.7
6JM6	−75	200	500	57	4.0	13.7	180	0.32	2.72	90.0	61.1	67.9	22.0	6.9
6JG6	−80	150	450	67	8.0	20.0	202	0.75	3.0	91.0	63.0	69.3	21.0	7.0

(1) Selected as optimum operating conditions.
(2) Calculated power lost in tank circuit.

Courtesy of Sylvania

Table 3

Class AB1 Operation ICAS — 30 MHz

Type	(1) E_{G1} V dc	(2) E_{G2} V dc	(2) E_p V dc	(1) I_p 0 Signal mA dc	I_{G2} mA dc	I_p mA dc	Plate Power 0 Signal Watts	Grid 2 Dissipation Watts	Plate Input Power Watts	RF Power Output Watts	Peak Envelope Power (PEP) Watts	Efficiency (%)	Plate Dissipation Watts	(3) Circuit Loss Watts
6GJ5	−43	200	500	30	3.8	85	15	0.76	42.5	17.5	35.0	41.5	22.0	3.0
6HF5	−46	140	500	40	4.5	133	20	0.63	66.5	28.8	57.6	43.0	35.0	2.7
6JB6	−42	200	500	30	4.2	85	15	0.84	42.5	17.5	35.0	41.5	22.0	3.0
6JE6	−44	125	500	40	3.9	110	20	0.49	55.0	23.4	46.8	42.6	30.0	2.6
6JM6	−42	200	500	30	4.4	85	15	0.88	42.5	18.3	36.6	43.1	22.0	2.2
6JG6	−35	150	450	30	4.5	98	13.5	0.67	44.0	18.9	37.8	43.0	21.0	4.1

(1) E_{G1} adjusted to indicated I_p (zero signal).
(2) Optimum conditions for providing best linearity and efficiency.
(3) Calculated power loss in tank circuit.

Courtesy of Sylvania

the upper limit, but some transceiver manufacturers use up to 650 volts. Most sweep tubes have sufficient internal-element spacings and insulation to take up to 1000 volts. The test circuit used by Sylvania is given in Fig. 5.

Closing Comments

Are sweep tubes suitable for amateur service? Tables 1, 2 and 3 offer hard proof that they can be used advantageously. They seem to be especially suited to Class C service in terms of efficiency. The cw operator should find them excellent for the purpose.

Practical experience has proved that these tubes can be pushed in excess of their ratings at low duty cycles. Remember the days when some of us ran our Class C 807s or 1625s with 1000 plate volts and higher-than-rated plate current? Rule number 1 was "don't hold the key down for more than a few seconds." If this rule were observed, many hours of operation at elevated power output could be had, but the longevity of the tubes was shortened as a tradeoff. If the reader wishes to "push" some sweep tubes (although it is not recommended), he or she should be prepared to replace them more frequently than if they are held within the prescribed ratings. QST

Notes

[1]DeMaw, "Some Ground Rules for Sweep-Tube Linear-Amplifier Design," *QST*, July 1968, p. 30.
[2]DeMaw and Hayward, *Solid State Design for the Radio Amateur*, chapter 4, ARRL, 1977.
[3]DeMaw, "A Husky Power Supply for Sweep Tube Amplifiers," *QST*, December 1969.

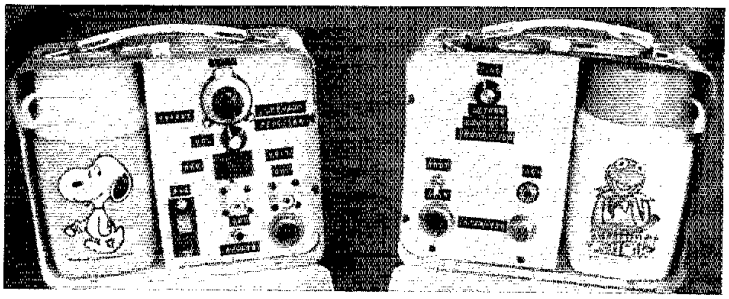
Strays

ABOUT PROJECT GOODWILL . . .

☐ No, it's *not* dead! The project was put on ice while the staff was at WARC-79, but it is now back in full swing, and we're slowly but surely matching a backlog of generous donors to recipients in developing countries. We apologize for this inevitable delay, but want to assure those clubs and individuals who have been patiently awaiting some word from Hq. that your money is safe, and you will soon be matched.

The success of the project was evident in Geneva during WARC, with favorable remarks being received from a number of developing countries' administrations. In addition, several kits were distributed on site in Geneva to delegates who expressed a genuine interest in promoting the Amateur Service in their countries.

Watch *QST* for periodic updates on the project. And thanks!



This novel job of packaging the Herring-Aid Five receiver (July 1976 *QST*) in the Charlie Brown lunchbox and the Tuna-Tin 2 transmitter (May 1976 *QST*), CB Slider (March 1977 *QST*) and Codzila 1 (February 1977 *QST*) in the Muppet Show lunchbox was done by Bill Barfield, WB5PRR, Satartia, MS. Bill built the panels with sheet metal. Since the thermos bottles still fit in the units, carrying liquid refreshment is easy.

DO YOU SEND QSL CARDS TO BOX 88?

☐ Walt Brown, KAØDMB, Omaha, NE, recently worked his first Russian station, a UA3 near Moscow. Walt sent a QSL direct, with an IRC to guarantee a prompt return. Not only did Walt get a return, but the Russian ham enclosed a very nice two-page letter. The letter described his homemade equipment, some personal information and Amateur Radio experience. In addition, the Russian ham asked that the following information, concerning QSL procedures, be passed on: (1) Please do not use call signs on envelopes. (2) Only QSL cards, and not enclosures such as IRCs, should be sent via the QSL bureau address, Box 88 in Moscow. — *Dick Jugel, KØDG, Omaha, NE*

Radio direction finding is very popular in the People's Republic of China. This picture was taken by a reporter from the Chinese Sports Illustrated News Agency at a direction-finding contest. Although the equipment is made in China, details on construction, frequencies, call signs and modulation are as rare as a BY QSL. *(photo courtesy HB9AQZ)*